

CLAIMS

What is claimed is:

1. A process of making a composite article comprising:
 - providing a trilayer structure comprising:
 - a first electrode layer,
 - an electrolyte layer,
 - a second electrode layer,
 - sintering the trilayer structure.
2. A process of making a composite article as claimed in claim 1, wherein
 - the first electrode layer comprises one or more electronic and/or MIEC and an ionic conductor or MIEC,
 - the electrolyte layer comprises predominately an ionically conducting electrolyte material, and
 - the second electrode layer comprising one or more electronic and/or MIEC and an ionic conductor or MIEC.
3. A process of making a composite article as claimed in claim 2, wherein the MIEC is non-reactive with the electrolyte layer material at the sintering temperature of the composite article.
4. A process of making a composite article as claimed in claim 1, wherein the first and/or second electrode comprise particles that are larger than about .25 μm but less than about 10 μm .
5. A process of making a composite article as claimed in claim 1, wherein

the electrolyte layer has a porosity of less than 5%.

6. A process of making a composite article as claimed in claim 1, wherein the electrode layers have a porosity of greater than 20 % but less than about 60%.
7. A process of making a composite article as claimed in claim 1, wherein the trilayer structure is affixed to a substrate.
8. A process of making a composite article as claimed in claim 7, wherein the substrate comprises a porous non-noble transition metal, a porous non-noble transition metal alloy or a porous cermet incorporating one or more of a non-noble non-nickel transition metal and a non-noble transition metal alloy.
9. A process of making a composite article as claimed in claim 1, wherein the sintering is conducted at a temperature sufficient to substantially sinter and densify the electrolyte layer without melting the electrodes.
10. A process of making a composite article as claimed in either of claims 1 or 9, wherein the sintering is conducted at about 1000 °C to about 1500 °C.
11. A process of making a composite article as claimed in claim 10, wherein the sintering is conducted at about 1200 °C to about 1400 °C.
12. A process of making a composite article as claimed in claim 11, wherein the sintering is conducted at about 1250 °C to about 1350 °C.
13. A process of making a composite article as claimed in claim 1, wherein the sintered electrolyte layer is gas-tight and greater than about 90% densified.
14. A process of making a composite article as claimed in claim 1, wherein the sintered electrolyte layer is gas-tight and greater than about 95% densified.

15. A process of making a composite article as claimed in claim 1, wherein the sintered electrolyte layer is no more than 2% porous.
16. A process of making a composite article as claimed in claim 1, wherein the sintered electrolyte layer is about 1 to 50 microns thick.
17. A process of making a composite article as claimed in claim 16, wherein the sintered electrolyte layer is about 3 to 30 microns thick.
18. A process of making a composite article as claimed in claim 17, wherein the sintered electrolyte layer is about 5 to 20 microns thick.
19. A process of making a composite article as claimed in claim 1, wherein said trilayer structure is planar.
20. A process of making a composite article as claimed in claim 1, wherein said trilayer structure is tubular.
21. A process of making a composite article as claimed in claim 1, wherein said trilayer structure is hexagonal.
22. A process of making a composite article as claimed in claim 7, wherein said substrate is an alloy selected from the group consisting of a low-chromium ferritic steel, an intermediate-chromium ferritic steel, a high-chromium ferritic steel, a chrome-based alloy, and chrome-containing nickel-based Inconel alloy.
23. A process of making a composite article as claimed in claim 22, wherein said alloy is selected from the group consisting of Cr₅Fe₁Y and Inconel 600.

24. A process of making a composite article as claimed in claim 7, wherein said substrate material is a cermet selected from the group consisting of at least one of $\text{La}_{1-x}\text{Sr}_x\text{Mn}_y\text{O}_{3-\delta}$ ($1 \geq X \geq 0.05$) ($0.95 \leq Y \leq 1.15$) ("LSM"), $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$ ($1 \geq X \geq 0.10$) ("LSC"), $\text{SrCo}_{1-x}\text{Fe}_x\text{O}_{3-\delta}$ ($0.30 \geq X \geq 0.20$), $\text{La}_{0.6}\text{Sr}_{0.4}\text{Co}_{0.6}\text{Fe}_{0.4}\text{O}_{3-\delta}$, $\text{Sr}_{0.7}\text{Ce}_{0.3}\text{MnO}_{3-\delta}$, $\text{LaNi}_{0.6}\text{Fe}_{0.4}\text{O}_{3-\delta}$, $\text{Sm}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$, yttria stabilized zirconia (YSZ), scandia stabilized zirconia (SSZ), $(\text{CeO}_2)_{0.8}(\text{Gd}_2\text{O}_3)_{0.2}$ (CGO), $\text{La}_{0.8}\text{Sr}_{0.2}\text{Ga}_{0.85}\text{Mg}_{0.15}\text{O}_{2.825}$ (LSGM20-15), $(\text{Bi}_2\text{O}_3)_{0.75}(\text{Y}_2\text{O}_3)_{0.25}$ and alumina, in combination with at least one of transition metals Cr, Fe, Cu, Ag, an alloy thereof, a low-chromium ferritic steel, an intermediate-chromium ferritic steel, a high-chromium ferritic steel, a chrome-based alloy, and chrome-containing nickel-based Inconel alloy.
25. A process of making a composite article as claimed in claim 24, wherein the LSM is selected from the group consisting of $\text{La}_{0.8}\text{Sr}_{0.2}\text{MnO}_{3-\delta}$, $\text{La}_{0.65}\text{Sr}_{0.30}\text{MnO}_{3-\delta}$, $\text{La}_{0.45}\text{Sr}_{0.55}\text{MnO}_{3-\delta}$.
26. A process of making a composite article as claimed in claim 25, wherein said chrome based alloy is Cr5Fe1Y.
27. A process of making a composite article as claimed in claim 1, wherein said electrolyte comprises at least one of yttria stabilized zirconia (YSZ), scandia stabilized zirconia (SSZ), doped cerium oxide including $(\text{CeO}_2)_{0.8}(\text{Gd}_2\text{O}_3)_{0.2}$ (CGO), $\text{La}_{0.8}\text{Sr}_{0.2}\text{Ga}_{0.85}\text{Mg}_{0.15}\text{O}_{2.825}$ (LSGM20-15) and $(\text{Bi}_2\text{O}_3)_{0.75}(\text{Y}_2\text{O}_3)_{0.25}$.
28. A process of making a composite article as claimed in claim 27, wherein said electrolyte is yttria stabilized zirconia.

29. A process of making a composite article as claimed in claim 28, wherein said yttria stabilized zirconia is $(\text{ZrO}_2)_x(\text{Y}_2\text{O}_3)_y$ where $(.88 \geq X \geq .97)$ and $(.03 \leq y \leq .12)$.
30. A process of making a composite article as claimed in claim 29, wherein said yttria stabilized zirconia is at least one of $(\text{ZrO}_2)_{0.92}(\text{Y}_2\text{O}_3)_{0.08}$ and $(\text{ZrO}_2)_{0.90}(\text{Y}_2\text{O}_3)_{0.10}$.
31. A process of making a composite article according to claim 1, wherein the electrolyte is a mixed ionic electronic conductor.
32. A process of making a composite article as claimed in claim 31, wherein said electrolyte comprises at least one of $\text{SrCo}_{1-x}\text{Fe}_x\text{O}_{3-\delta}$ ($0.30 \geq X \geq 0.20$), $\text{La}_{0.6}\text{Sr}_{0.4}\text{Co}_{0.6}\text{Fe}_{0.4}\text{O}_{3-\delta}$, $\text{Sm}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ and $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$.
33. A process of making a composite article as claimed in claim 32, wherein said electrolyte is $\text{SrCo}_{0.75}\text{Fe}_{0.25}\text{O}_{3-\delta}$.
34. A process of making a composite article as claimed in claim 1, wherein the composite article has an ohmic area specific resistance from about 0.5 ohm cm^2 to about $.05 \text{ ohm cm}^2$ during operation of the composite article.
35. A composite article made according to the process of claim 1, wherein the composite article has an ohmic area specific resistance of from about 0.5 ohm cm^2 to about $.25 \text{ ohm cm}^2$ during operation of the composite article.
36. A composite article made according to the process of claim 1, wherein the composite article has an ohmic area specific resistance of less than about $.05 \text{ ohm cm}^2$ during operation of the composite article.
37. A solid oxide fuel cell made according to the process of claim 1.

38. A process of making a solid oxide fuel cell comprising:

providing a trilayer structure comprising:

a first electrode layer,

an electrolyte layer,

a second electrode layer,

sintering the trilayer structure.

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